IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Serial No. 09/961,205 Filed September 24, 2001
(Attorney Docket No. GP-300567)

Goro Tamai
William L. Aldrich III
Tony T. Hoang
Patrick L. Risse Group 3618

APPARATUS AND METHOD FOR
CONTROLLING A HYBRID VEHICLE Examiner Bridget D. Avery

AFFIDAVIT UNDER 37 CFR 1.131

Commissioner for Patents
Washington DC 20231

Goro Tamai, being duly sworn, deposes and says:

William L. Aldrich III, being duly sworn, deposes and says:

Tony T. Hoang, being duly sworn, deposes and says:

1. I am an inventor of claims 25-30 of the patent application identified above and an inventor of the subject matter described and claimed therein.

2. Prior to May 8, 2000, having earlier conceived of the idea for the invention "Apparatus and Method for Controlling a Hybrid Vehicle," and with due diligence, I reduced the invention as evidenced by the attached invention disclosure form and documentation. The dates have been redacted from the invention disclosure and documentation.

Goro Tamai

William L. Aldrich III

Tony T. Hoang

Subscribed and sworn to before me this 2ND day of MARCH, 2003.

Stephen R. Kornblum
Notary Public

STEPHEN R. KORNBLUM
Notary Public, Oakland County, MI
My Commission Expires Apr. 4, 2003

General Motors Corporation
Legal Staff
300 Renaissance Center
Mail Code 482-C23-B21
PO Box 300
Detroit MI 48265-3000

Attachment

SATURN CORPORATION

File No. S-342-02-00

RECORD OF INVENTION
Part 1

This Record of Invention (Part 1) provides for the disclosure of your invention with the minimum detail necessary for an initial evaluation by a Review Board consisting of engineering/t[illegible]t & Legal Staff personnel. The Review Board will consider novelty and competitive si[illegible]ining the appropriate disposition of your invention. If the Review Board decides to pursue a patent on your invention, you will be required to prepare a Record of Invention (Part 2) containing the detailed disclosure necessary to enable the preparation of a patent application. If the Review Board decides to publish your invention, you will be provided instructions for preparing a disclosure for publication.

Invention Title: Logic System to Determine Degree of Powertrain Hybridization for the Saturn MoGen System

Inventor #1

Name: Goro (First Name) | (Middle Initial) | Tamai (Last Name) Citizen of: Japan

Social Security No. 134-70-2665 Saturn Employee: ☒ Yes ☐ No ☒ Salary ☐ Hourly ☐ Contract

Home Address: 31375 Willow Court (Street) Warren, MI (City and State) 48093 (Zip Code)

Work Address: 434 W. 12 Mile Road, Madison Heights, MI 48071 Mail Code: 480-990-7025

FAX Number: (8)-258-7157 (Centrex Number) Work Phone No. (8)-258-5642 (Centrex Number) 248-524-5642 (Area Code) + Number 480-966122

Non-Saturn Employer: Phone No. (Area Code) + Number

Non-Saturn Employer Address: (Street) (City and State) (Zip Code)

Inventor #2

Name: William (First Name) | L (Middle Initial) | Aldrich III (Last Name) Citizen of: USA

Social Security No. 365-64-8331 Saturn Employee: ☒ Yes ☐ No ☒ Salary ☐ Hourly ☐ Contract

Home Address: 11375 Eagle Rd (Street) Davisburg, MI (City and State) 48350 (Zip Code)

Work Address: 434 W. 12 Mile Road, Madison Heights, MI 48071 Mail Code: 480-990-084

FAX Number: (8)-258-6902 (Centrex Number) Work Phone No. (8)-258-5742 (Centrex Number) 248-524-5742 (Area Code) + Number

Non-Saturn Employer: Phone No. (Area Code) + Number

Non-Saturn Employer Address: (Street) (City and State) (Zip Code)

File Number: S 342-02-00

Inventor #3

Name: Tony (First Name) T (Middle Initial) Hoang (Last Name) Citizen of: USA

Social Security No. 586-44-4303 Saturn Employee: ☒ Yes ☐ No ☐ Salary ☐ Hourly ☐ Contract

Home Address: 27868 Thomas (Street) Warren, MI (City and State) 48092 (Zip Code)

Work Address: 434 W. 12 Mile Mail Code: 480-990-071

FAX Number: (8)-258-7157 (Centrex Number) Work Phone No. (8)-258-6915 (Centrex Number) 248-524-6915 (Area Code) + Number

Non-Saturn Employer: Phone No. (Area Code) + Number

Non-Saturn Employer Address: (Street) (City and State) (Zip Code)

Inventor #4

Name: (First Name) (Middle Initial) (Last Name) Citizen of:

Social Security No. Saturn Employee: ☐ Yes ☐ No ☐ Salary ☐ Hourly ☐ Contract

Home Address: (Street) (City and State) (Zip Code)

Work Address: Mail Code:

FAX Number: (8)- (Centrex Number) Work Phone No. (8)- (Centrex Number) (Area Code) + Number

Non-Saturn Employer: Phone No. (Area Code) + Number

Non-Saturn Employer Address: (Street) (City and State) (Zip Code)

Inventor #5*

Name: (First Name) (Middle Initial) (Last Name) Citizen of:

Social Security No. Saturn Employee: ☐ Yes ☐ No ☐ Salary ☐ Hourly ☐ Contract

Home Address: (Street) (City and State) (Zip Code)

Work Address: Mail Code:

FAX Number: (8)- (Centrex Number) Work Phone No. (8)- (Centrex Number) (Area Code) + Number

Non-Saturn Employer: (Area Code) + Number

Non-Saturn Employer Address: (Street) (City and State) (Zip Code)

* If there are additional inventors on a ROI use the template at the end of this form.

File Number: S-342-02-00

I hereby assign this invention to Saturn Corporation and authorize Saturn Corporation to file a patent application on my behalf.

INVENTOR - SIGNATURE	Goro Tamai (ALSO, PRINT NAME)	DATE
INVENTOR - SIGNATURE	William Aldrich III (ALSO, PRINT NAME)	DATE
INVENTOR - SIGNATURE	Tony T. Hoang (ALSO, PRINT NAME)	14Feb00 DATE
INVENTOR - SIGNATURE	(ALSO, PRINT NAME)	DATE
INVENTOR - SIGNATURE	(ALSO, PRINT NAME)	DATE

This invention was reviewed and understood by me:

1st WITNESS - SIGNATURE	CESAR CERTEZA (ALSO PRINT NAME)	DATE
2nd WITNESS - SIGNATURE	KEN KRIDNER (ALSO, PRINT NAME)	DATE

Goro Tamai
William L. Aldrich III
Tony Hoang

Logic System to Determine Degree of Powertrain Hybridization

In the Saturn MoGen system (Patent Form S-330-20-98), an electric motor-generator (MoGen) system replaces the conventional starter motor and alternator. When the vehicle is decelerating or is stopped, the fuel flow to the engine is shut off to improve fuel economy. The MoGen system is implemented to enable this fuel-cutoff feature without sacrificing driveability. From a stop, upon brake-pedal release, the MoGen system creeps the vehicle forward while turning the gas engine to start it. When the engine is running, the MoGen acts as a generator to supply the vehicle's electrical power requirements as well as recharging the battery pack. When the engine is off, the vehicle's electrical loads (fans, radio, etc.) are supported by the battery system and a DCDC converter. The MoGen also acts as a motor during fuel-off deceleration downshifts to synchronize the engine and transmission speeds (Patent Form S-330-01-99).

The focus of this patent is how the MoGen hybrid system determines the "Degree of Hybridization." "Degree of Hybridization" relates to the level or degree to which the MoGen hybrid system interacts with, or replaces, the normal functions of the internal combustion engine. The MoGen hybrid system allows many new and unique forms of powertrain control previously unavailable with conventional engine starter and alternator control schemes. Conventional starter control only allows the starter motor to apply torque to the internal combustion engine during a crank event. Conventional alternator control simply charges to a setpoint voltage. Conversely, since the MoGen system is in constant mesh with the internal combustion engine, the MoGen system can be used to optimize control for all internal combustion engine operational modes. Additionally, the enhanced control of charging capabilities allows a much more efficient control methodology. Therefore, in accordance with the increased control capabilities, a control system must exist to take advantage of the increased opportunities offered by the MoGen hybrid hardware. The control system has been segmented into eight discrete degrees:

1. **Degree 1: Full Hybrid:** Fuel cutoff exercised on decelerations and stops (engine off), with MoGen-aided downshift engine-speed synchronization and Inertia-Eliminator application (Patent Form S-330-xx-00).
2. **Degree 2: Full Hybrid w/ Fuel-Aided Downshifts:** Fuel cutoff is exercised during decelerations and stops (engine off), Inertia Eliminator is active, but downshift engine-speed synchronization is performed by both combustion and electric power.
3. **Degree 3: Decel-Only Hybrid:** Fuel cutoff exercised only on decelerations. Fuel delivery is restarted just before the Drop-to-Neutral speed (Patent Form S-330-20-98). The downshift engine speed synchronization is performed by the MoGen. Inertia Eliminator is active.
4. **Degree 4: Decel-Only Hybrid w/o Inertia Eliminator:** Same as "Decel-Only Hybrid" but Inertia Eliminator is not active.
5. **Degree 5: Decel-only Hybrid w/ Fuel-Aided Downshifts:** Fuel cutoff exercised only on decelerations. Fuel delivery is restarted just before the Drop-to-Neutral speed (Patent Form S-330-20-98). The downshift engine speed synchronization is performed by both combustion and Mogen. Inertia Eliminator is not active.
6. **Degree 6: Decel-only Hybrid w/ Fuel-Aided Downshifts, w/o Inertia Eliminator:** Same as "Decel-Only Hybrid w/ Fuel-Aided Downshifts" but Inertia Eliminator is not active.
7. **Degree 7: No Hybridization:** No fuel cutoff is exercised during decelerations or stops, Inertia Eliminator is not active, and MoGen-aided downshift synchronization is disabled.
8. **Degree 8: Engine Start / Crank:** Mogen unit is used as a starter motor for the internal combustion engine (Patent application S-xxx-xxx-00).

S-342-02-00

The difference between Degree 1 and 2 is that in Degree 2, the speed sychronization is performed by both electric power and combustion power. As discussed in Patent Form S-330-20-98, during a deceleration, the transmission system must perform a downshift so that the transmission will be in the proper gear if the driver wishes to reaccelerate. In order to perform the downshift, the engine speed must be raised between the release of one gear and the engagement of the lower gear. Additionally, when a vehicle is decelerating down a steep grade, the powertrain system may command a downshift at a higher speed than when driving on flat or uphill terrain. At this higher engine speed, the MoGen may not have enough torque to properly perform the speed synchronization. For this reason, under these MoGen-limited conditions, the spark and fuel is blended in (engine is already spinning) during the speed synchronization to aid the MoGen.

The difference between Degree 3 and 4 is the implementation of the "Inertia Eliminator" concept. To make the operation of the hybrid system as transparent as possible, the added rotational inertia of the MoGen system can be virtually eliminated by powering the MoGen to accelerate itself and its components during rapid throttle-application transients. This makes the powertrain more responsive to driver input. This differs from "power assist" in that the spike of MoGen power only indirectly contributes to vehicle acceleration. With the torque converter clutch open, the inertia eliminator spike of power raises the engine speed more rapidly so that the engine is at a more favourable portion of its torque curve, and thus enabling the vehicle to accelerate better. If the battery state-of-charge is not sufficiently high, the inertia elimination system is disabled.

The utilized degree of hybridization is a function of the following variable conditions.

1) Battery SOC:
   a) Low (e.g. SOC < 50%)
   b) Med (e.g. SOC = 50-75%)
   c) High (e.g. SOC >75%)
2) Ambient Temperature (Tamb):
   a) Low (e.g. Tamb < 10 deg. C)
   b) Med (e.g. Tamb = 5-15 deg. C)
   c) High (e.g. Tamb > 15 deg. C)
3) Engine Coolant Temperature (ECT):
   a) Low (e.g. ECT < 0 deg. C)
   b) Med (e.g. ECT = 0 - 40 deg. C)
   c) High (e.g. ECT > 40 deg. C)
4) A/C – Heater Blower setting:
   a) Low
   b) Med
   c) High
5) A/C request state (on or off).
6) Downshift engine synchronization speed requirement.
7) Ignition key position.
8) ~~Cruise control request state (on or off).~~ ~~Not so important~~ scratch b/c emission defeater
9) Overrides based on diagnostics, failure modes, faults.

The flow chart shown in Figure 1details how the hybridization degree is chosen.

S-342-02-00

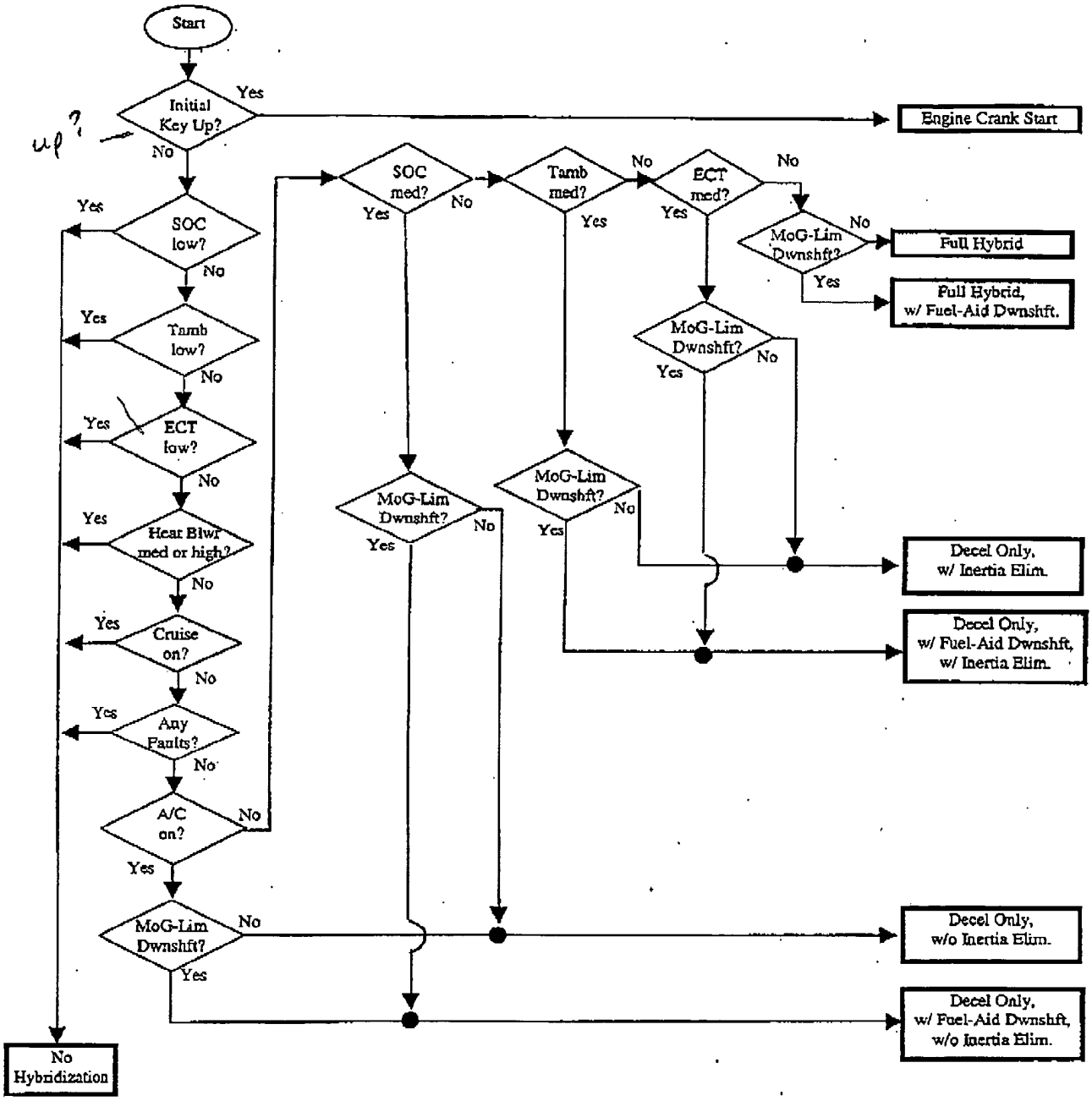


Figure 1: Flow chart to determine degree of hybridization in the Saturn MoGen hybrid system.

SATURN CORPORATION

File No. S-342-02-00
GP-300567

RECORD OF INVENTION
Part 2

This Record of Invention (Part 2) provides for the disclosure of the information necessary to enable the preparation of a patent application for your invention and to enable compliance with the legal requirements for obtaining patent protection.

1. File number as identified in the Record of Invention (Part 1): S-342-02-00

2. Identify below any ***changes*** to the corresponding information provided on page 1 of the Record of Invention (Part 1):

Inventor #

Name: _____ (First Name) _____ (Middle Initial) _____ (Last Name) Citizen of: _____

Social Security No. _____ Saturn Employee: ☐ Yes ☐ No ☐ Salary ☐ Hourly ☐ Contract

Home Address: _____ (Street) _____ (City and State) _____ (Zip Code)

Work Address: _____ Mail Code: _____

FAX Number: (8)- _____ (Centrex Number) Work Phone No. (8)- _____ (Centrex Number) _____ (Area Code) + Number)

Non-Saturn Employer: _____ Phone No. _____ (Area Code) + Number)

Non-Saturn Employer Address: _____ (Street) _____ (City and State) _____ (Zip Code)

Inventor #

Name: _____ (First Name) _____ (Middle Initial) _____ (Last Name) Citizen of: _____

Social Security No. _____ Saturn Employee: ☐ Yes ☐ No ☐ Salary ☐ Hourly ☐ Contract

Home Address: _____ (Street) _____ (City and State) _____ (Zip Code)

Work Address: _____ Mail Code: _____

FAX Number: (8)- _____ (Centrex Number) Work Phone No. (8)- _____ (Centrex Number) _____ (Area Code) + Number)

Non-Saturn Employer: _____ Phone No. _____ (Area Code) + Number)

Non-Saturn Employer Address: _____ (Street) _____ (City and State) _____ (Zip Code)

LEGAL STAFF File Number: S-342-02-00
GP-300567

1. This invention was first thought of on: System developed over

2. Please list all the individuals who can provide information relating to the making of the invention. This list may include individuals who made the first sketch, description, or tests and individuals who are familiar with the facts relating to the making of the invention.
Robert C. Downs, Dennis Richey, Joel Taylor.

3. Each inventor has a legal duty to disclose all information known that is material to patentability. Such information includes the relevant prior art, which may be in the form of current or past products, equipment, processes, materials, patents, publications, advertisements, displays, and unpublished developments and proposals--whether originated by you, others in Saturn, GM, competitors, suppliers, customers or others. Such information also includes disclosure of this invention outside Saturn, sales and offers of products using this invention, use of this invention in production and disputes about who should be considered as an inventor of this invention. To comply with the duty to disclose, list here and attach a copy of all such information, to the extent known.

N/A

4. Describe the background of the invention. This description may include the state of the prior art and problems associated with the prior art that are overcome by this invention.

The goal of this hybrid powertrain is to increase fuel economy by exercising fuel-cutoff during decelerations and stops. This Degrees-of-Hybridization (DoH) system varies the extent of fuel cutoff and interaction of the electric machine with the heat engine to maximize fuel savings while not sacrificing passenger comfort, driveability, and component longevity (e.g. battery life).

5. Summarize what you consider to be the general underlying principles of this invention.

This DoH control system varies the extent of engine fuel cutoff and task electrification as a function of battery state-of-charge, ambient temperature, engine coolant temperature, air-conditioner switch, transmission downshift synchronization requirements, and fault diagnostics information.

6. Attach a complete description of the invention. In order to meet legal requirements, the description must be of the best mode contemplated by the Inventor(s) of carrying out the invention at a level enabling one skilled in the art to make and use the invention. Following are guidelines for preparation of the description:

Mechanical Devices: Include a detailed description and drawings which illustrate all essential elements of the invention and the environment in which it is used. The description should describe the structure key-numbered to the drawing(s) and the operation of the structure including the functional relationship between all elements. To the extent known, alternate embodiments should be described.

Electrical Devices: The description for hardware-based electrical devices is the same as for Mechanical Devices.

Circuit-based inventions: Include a detailed description and circuit diagrams reduced to standard components for parts of the circuit that are new. Standard components, such as amplifiers, microprocessors, logic gates, etc. can be represented as labeled blocks. The description should describe all of the blocks and components of the circuit and their interaction.

Computer program-based inventions: Include a detailed description, a schematic of the components monitored and/or controlled by the program, the physical structure (such as the computer memory) associated with the program, and a general functional flow chart of the program illustrating the steps of the program in carrying out the invention at a level of detail from which one skilled in the art can understand and implement the program. The description should set forth the operation of the program, describing each element of the flow chart and its relationship or interaction with the components monitored and/or controlled by the program.

Chemical Inventions (materials and/or processes for making them or for using them to make other things): Identify all essential materials (in chemical terms-not tradenames) used and alternatives therefor. All significant variables needed to define the invention must be identified, quantified and discussed. Depending on the nature of the invention, such variables might include: treatment/reaction times, temperature, pressure, concentration, particle shape/size, viscosity, crystal structure, phases, porosity, pH, density, tensile strength, polymer chain length, etc. Each variable should be quantified in terms of an operative range and a preferred embodiment, e.g. "The heat treatment is carried out between 100°C and 200°C (preferably 165°C)." The function/purpose of each variable should be described including a statement as to what happens if the variable falls outside the operative range, e.g. "Component A serves as a plasticizer for Component B. Below 100°C, Component A will not mix with Component B, and above 200°C it evaporates". Finally, a recipe for at least one detailed working example should be provided. Preferably, several such examples will be provided covering the full range of the significant variables used to define the invention.

Processes : Include a schematic of the components monitored, controlled and/or created by the process and a flow chart of the process illustrating the steps of the process at a level of detail from which one skilled in the art can understand and implement the process. The description should set forth the operation of the process describing each step of the flow chart and its relationship or interaction with the components monitored, controlled and/or created by the process.

7. Provide any additional information that may help in understanding the invention or aid in the preparation of a patent application for your invention: (attach additional pages if necessary)

Please see attached sheets.

I hereby assign this invention to Saturn Corporation and authorize Saturn Corporation to file a patent application on my behalf.

INVENTOR - SIGNATURE	Goro Tamai (ALSO, PRINT NAME)	DATE
INVENTOR - SIGNATURE	Tony T. Hoang (ALSO, PRINT NAME)	DATE
INVENTOR - SIGNATURE	William L. Aldrich III (ALSO, PRINT NAME)	DATE
INVENTOR - SIGNATURE	(ALSO, PRINT NAME)	DATE
INVENTOR - SIGNATURE	(ALSO, PRINT NAME)	DATE

This invention was reviewed and understood by me:

1st WITNESS - SIGNATURE	Glenn P. O'Connell (ALSO PRINT NAME)	DATE
2nd WITNESS - SIGNATURE	Anthony J. Corsetti (ALSO, PRINT NAME)	DATE

Goro Tamai
William L. Aldrich III
Tony Hoang

Control System to Determine Degree of Powertrain Hybridization

S-342-02-00
Part 2, Section 6

In the Saturn MoGen system (Patent Form S-330-20-98), an electric motor-generator (MoGen) system replaces the conventional starter motor and alternator. When the vehicle is decelerating or is stopped, the fuel flow to the engine is shut off to improve fuel economy. The MoGen system is implemented to enable this fuel-cutoff feature without sacrificing driveability. From a stop, upon brake-pedal release, the MoGen system creeps the vehicle forward while turning the gas engine to start it. When the engine is running, the MoGen acts as a generator to supply the vehicle's electrical power requirements as well as recharging the battery pack. When the engine is off, the vehicle's electrical loads (fans, radio, etc.) are supported by the battery system and a DCDC converter. The MoGen also acts as a motor during fuel-off deceleration downshifts to synchronize the engine and transmission speeds (Patent Form S-330-01-99).

The focus of this patent is how the MoGen hybrid system determines the "Degree of Hybridization." "Degree of Hybridization" relates to the level or degree to which the MoGen hybrid system interacts with, or replaces, the normal functions of the internal combustion engine. The MoGen hybrid system allows many new and unique forms of powertrain control previously unavailable with conventional engine starter and alternator control schemes. Conventional starter control only allows the starter motor to apply torque to the internal combustion engine during a crank event. Conventional alternator control simply charges to a setpoint voltage. Conversely, since the MoGen system is in constant mesh with the internal combustion engine, the MoGen system can be used to optimize control for all internal combustion engine operational modes. Additionally, the enhanced control of charging capabilities allows a much more efficient control methodology. Therefore, in accordance with the increased control capabilities, a control system must exist to take advantage of the increased opportunities offered by the MoGen hybrid hardware. The control system has been segmented into eight discrete degrees:

1. **Degree 1: Full Hybrid:** Fuel cutoff exercised on decelerations and stops (engine off), with MoGen-aided downshift engine-speed synchronization and Inertia-Eliminator application.
2. **Degree 2: Full Hybrid w/ Fuel-Aided Downshifts:** Fuel cutoff is exercised during decelerations and stops (engine off), Inertia Eliminator is active, but downshift engine-speed synchronization is performed by both combustion and electric power.
3. **Degree 3: Decel-Only Hybrid:** Fuel cutoff exercised only on decelerations. Fuel delivery is restarted just before the Drop-to-Neutral speed (Patent Form S-330-20-98). The downshift engine speed synchronization is performed by the MoGen. Inertia Eliminator is active.
4. **Degree 4: Decel-Only Hybrid w/o Inertia Eliminator:** Same as "Decel-Only Hybrid" but Inertia Eliminator is not active.
5. **Degree 5: Decel-only Hybrid w/ Fuel-Aided Downshifts:** Fuel cutoff exercised only on decelerations. Fuel delivery is restarted just before the Drop-to-Neutral speed (Patent Form S-330-20-98). The downshift engine speed synchronization is performed by both combustion and Mogen. Inertia Eliminator is active.
6. **Degree 6: Decel-only Hybrid w/ Fuel-Aided Downshifts, w/o Inertia Eliminator:** Same as "Decel-Only Hybrid w/ Fuel-Aided Downshifts" but Inertia Eliminator is not active.
7. **Degree 7: No Hybridization:** No fuel cutoff is exercised during decelerations or stops, Inertia Eliminator is not active, and MoGen-aided downshift synchronization is disabled.

8. **Degree 8: Engine Start / Crank:** Mogen unit is used as a starter motor for the internal combustion engine (Patent application S-341-01-00).

The difference between Degree 1 and 2 is that in Degree 2, the speed sychronization is performed by both electric power and combustion power. As discussed in Patent Form S-330-20-98, during a deceleration, the transmission system must perform a downshift so that the transmission will be in the proper gear if the driver wishes to reaccelerate. In order to perform the downshift, the engine speed must be raised between the release of one gear and the engagement of the lower gear. Additionally, when a vehicle is decelerating down a steep grade, the powertrain system may command a downshift at a higher speed than when driving on flat or uphill terrain. At this higher engine speed or if the batteries are low, the MoGen may not have enough torque to properly perform the speed synchronization. For this reason, under these MoGen-limited conditions, the spark and fuel is blended in (engine is already spinning) during the speed synchronization to aid the MoGen.

The difference between Degree 3 and 4 is the implementation of the "Inertia Eliminator" concept. To make the operation of the hybrid system as transparent as possible, the added rotational inertia of the MoGen system can be virtually eliminated by powering the MoGen to accelerate itself and its components during rapid throttle-application transients. This makes the powertrain more responsive to driver input. This differs from "power assist" in that the spike of MoGen power only indirectly contributes to vehicle acceleration. With the torque converter clutch open, the inertia eliminator spike of power raises the engine speed more rapidly so that the engine is at a more favourable portion of its torque curve, and thus enabling the vehicle to accelerate better. If the battery state-of-charge is not sufficiently high, the inertia elimination system is disabled.

The utilized degree of hybridization is a function of the following variable conditions.

1) Battery SOC:
   a) Low (e.g. SOC < 50%)
   b) Med (e.g. SOC = 50-75%)
   c) High (e.g. SOC >75%)
2) Ambient Temperature (Tamb):
   a) Low (e.g. Tamb < 10 deg. C)
   b) Med (e.g. Tamb = 5-15 deg. C)
   c) High (e.g. Tamb > 15 deg. C)
3) Engine Coolant Temperature (ECT):
   a) Low (e.g. ECT < 0 deg. C)
   b) Med (e.g. ECT = 0 - 40 deg. C)
   c) High (e.g. ECT > 40 deg. C)
4) A/C request state (on or off), and possibly blower setting depending on emissions legislation.
5) Downshift engine synchronization speed requirement.
6) Ignition key position.
7) Overrides based on diagnostics, failure modes, faults.

The flow chart shown in Figure 1details how the hybridization degree is chosen.

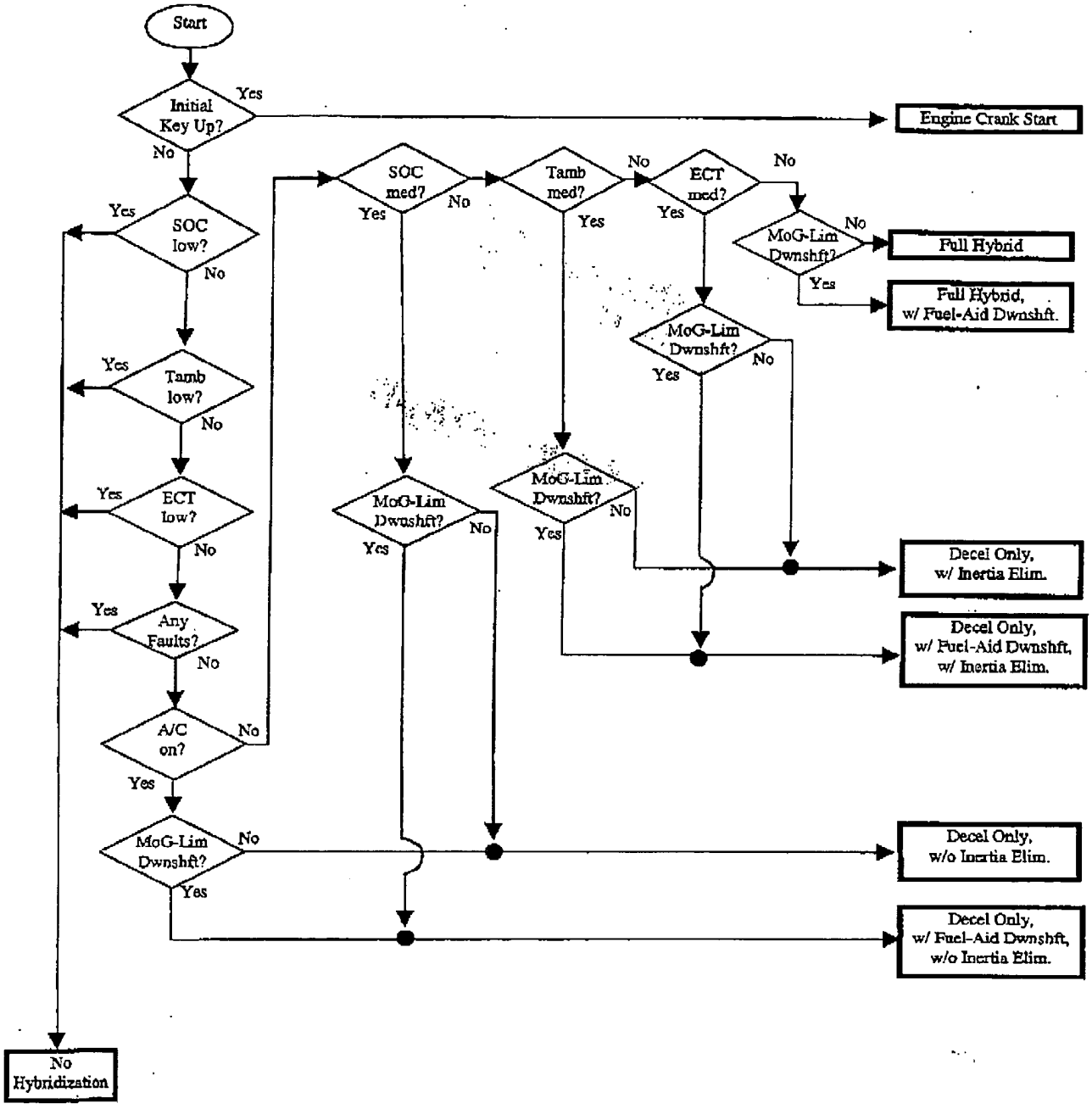


Figure 1: Flow chart to determine degree of hybridization in the Saturn MoGen hybrid system.

Memorandum

SATURN

Date:

Subject: Record of Invention Submission

To: Laura C. Wideman
GM Legal Staff
Intellectual Property

Attached is a Record of Invention Part 1 from Saturn Corporation. Please note the following information:

Subject: Logic System to Determine Degree of Powertrain Hybridization for the Saturn MoGen System.

Saturn #: S-342-02-00

Inventor(s): Goro Tamai
William L. Aldrich III
Tony T. Hoang

Attachments: Record of Invention Form Part 1
Description of Invention 2 Pages
Figures 1 Page

Please review this material for clearance and possible patentability. If you have any questions, please feel free to contact me at (248) 524-6937.

Robert J. Wyszumiala
Saturn Powertrain Patent Administrator

SATURN MoGen POWERTRAIN (MG42)

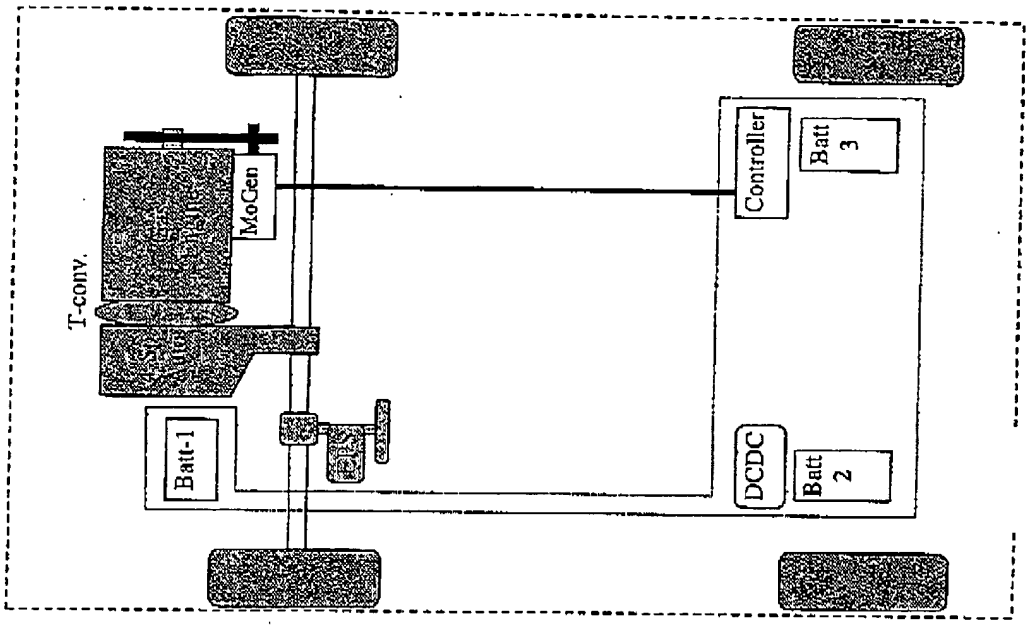
SATURN MOGEN OBJECTIVES

PROJECT

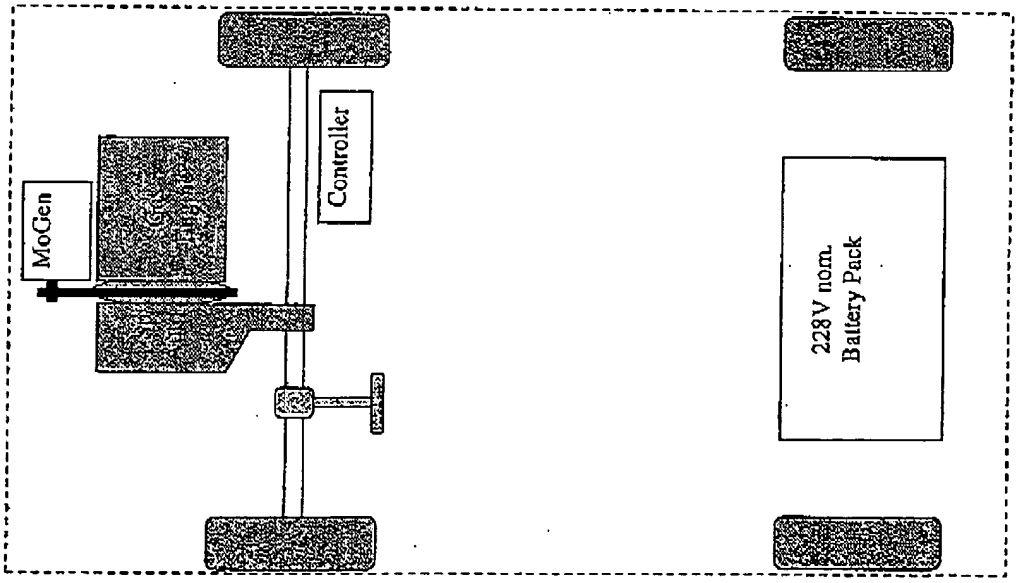
1. Develop hybrid engineering expertise.
2. Establish leadership position in industry.
3. Develop low-cost **TRANSPLANTABLE** system.

VEHICLE

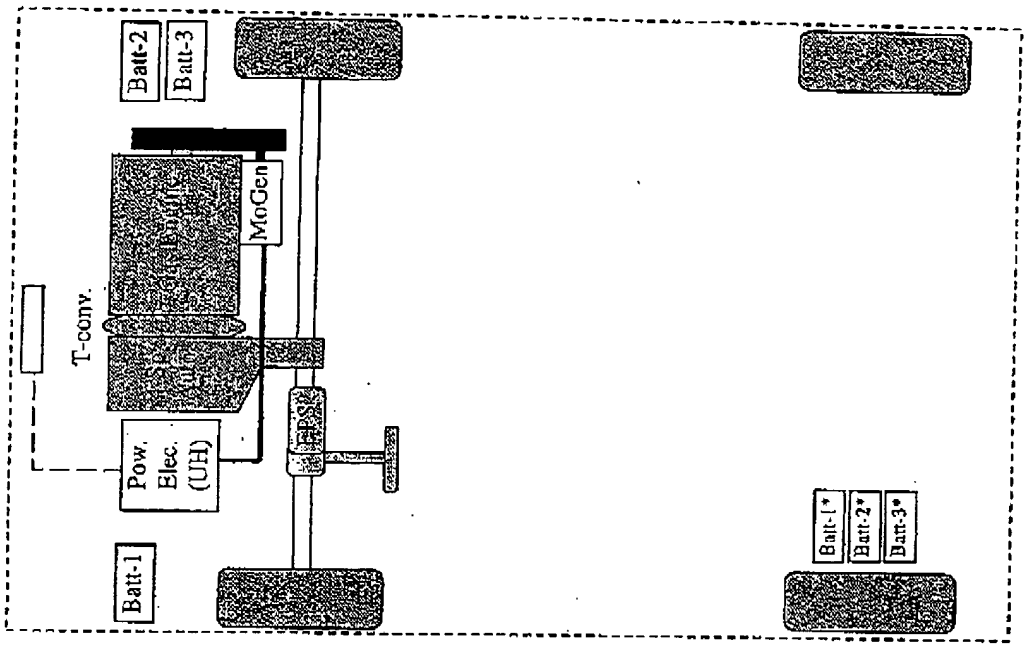
1. Leave Saturn powertrain and car "as is."
2. Improve Fuel economy by **fuel cutoff** during deceleration and idle.
3. Improve emissions by decreasing engine-on time during EPA tests.
4. Make operation transparent to the driver.
5. Add minimal EV drive to **enable** smooth engine stop/starts.



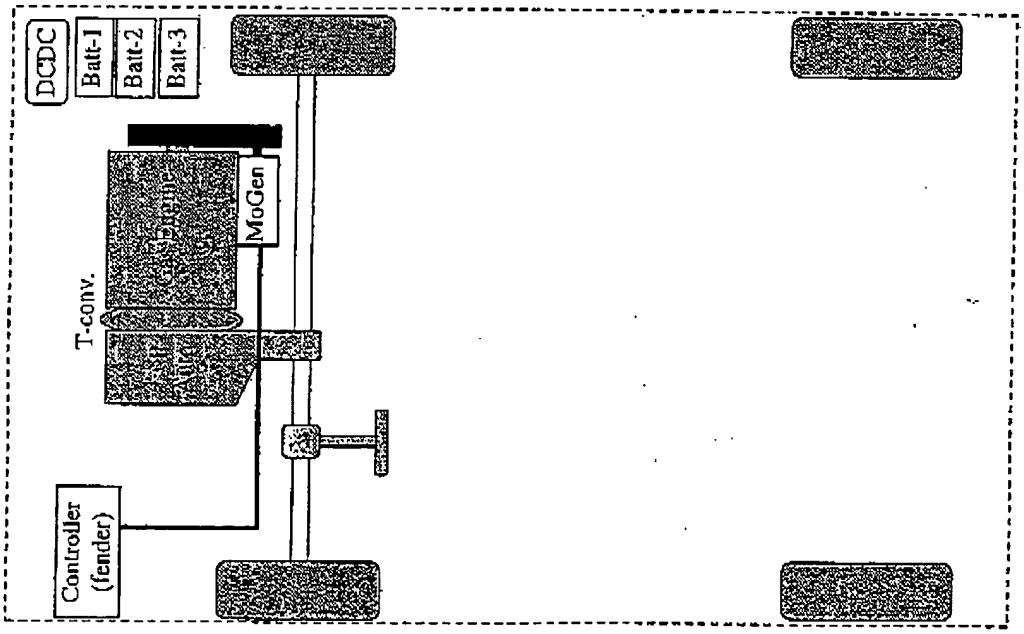
Hybrid Prototype
(DPG Show Car)



Hybrid Research Vehicle

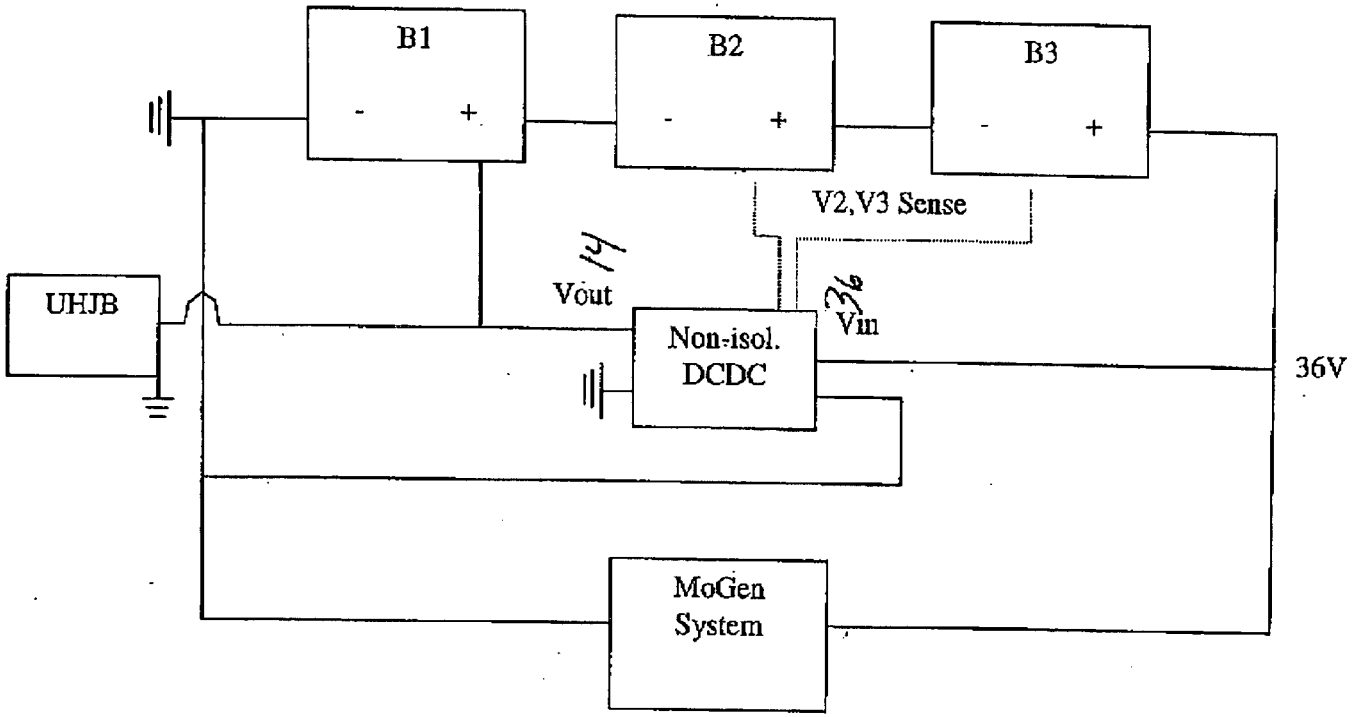


C Hybrid Prototype (H4, H5, H6*)

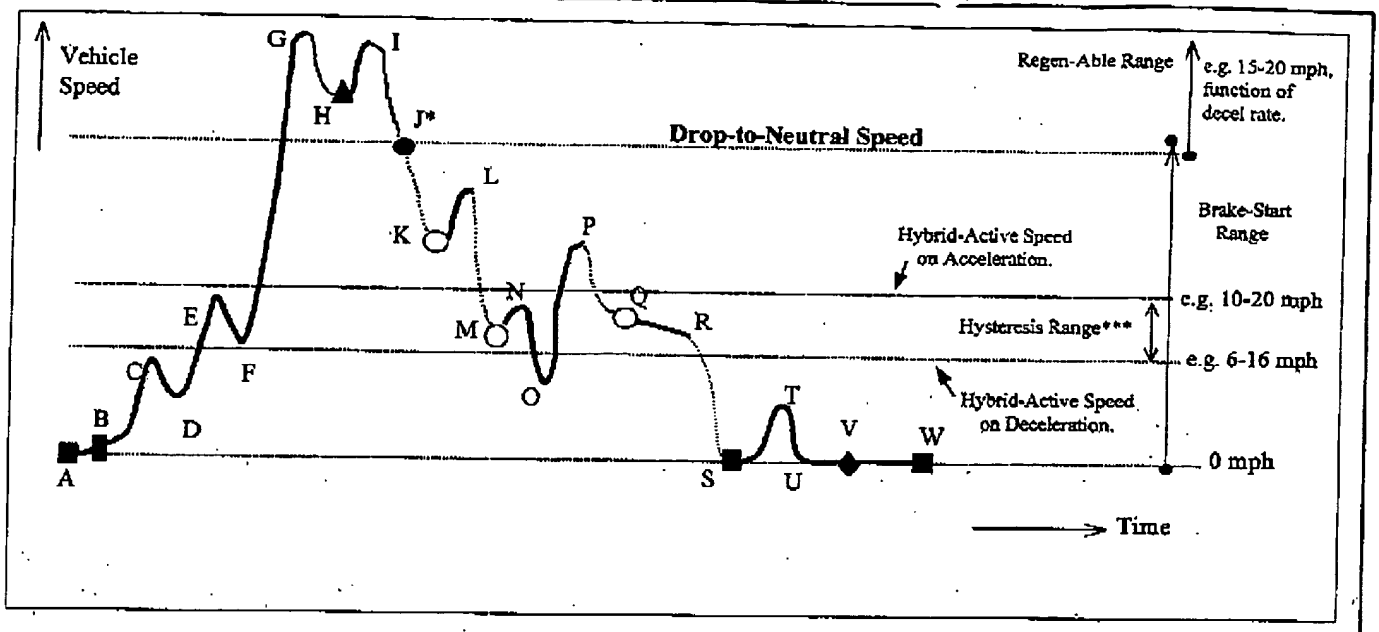


; Hybrid Prototype (H3)

ELECTRICAL SCHEMATIC



- Three 12V modules. B1 is chassis grounded.
- DCDC converter output in parallel w/ B1.
- DCDC Vout = Vmin, or min(V2,V3), or max(V2,V3).
- Regen Vlid = max(V2,V3) *3.
- Later: Bi-directional DCDC for jumpstarting.



■A: At stop w/ fuel off, release brake to electrically turn engine.
AB: Electrically creep.
■B: Fuel and spark delivered to start engine.
BC, CD, DE, EF, FG: Fuel on.
GH: Fuel off, regen.
▲H: Tip into gas pedal, start engine by delivering fuel and spark. (Use electric motor if engine rpm is lower than optimal.)
HI: Fuel on.
IJ*: Fuel off, regen.
● J: Drop to neutral (actually, drop to first gear and coast off its freewheel, i.e. effectively in neutral).
JK: Fuel off, coast (engine stalled).
○ K: Start engine with electric motor upon brake release (BPS threshold for start is x% of BPSmax, x is function of BPS apply rate).
KL: Fuel on.
LM: Fuel off, coast (engine stalled).
○M: Start engine with electric motor upon brake release.
MN, NO, OP: Fuel on.
PQ: Fuel off, coast (engine stalled).
○ Q: Start engine with electric motor upon brake release.
QR: Fuel on, but no application of gas pedal (continue to decelerate).
R: Shut off fuel upon brake application.
RS: Fuel off, coast (engine stalled).
■S: At stop w/ fuel off, release brake to electrically turn engine, and immediately apply gas pedal to fire engine.
ST, TU, UV: Fuel on.
◆V: At stop with engine idling (fuel on), fuel can be shut by bottoming out the brake pedal.**
VW: Fuel-off stop.
■W: Restart electrically with release of brake pedal.

To shut fuel off:
If in 1,2 gear, then fuel-off via BPS>0.
If in 3,4 gear (and V<=25 mph), then fuel-off via BPS>0.
If in 3,4 gear (and V>25 mph), then fuel-off via TPS=0.

* If the brake pedal is released in IJ, and the vehicle continues to decelerate (fuel-off) with no pedals applied, the fuel and spark will be delivered just before the Drop-to-Neutral speed is reached to restart the engine (with possible assist from the electric motor).
** Number of electric restarts allowable, without exceeding the Hybrid-Active speed, is limited to sustain battery state-of-charge.
*** Upper limit of hysteresis band moves up in speed with number of times exercised without exceeding a variable time at some speed.

Figure 1: Schematic of the Saturn Hybrid's fuel-control sequence as a function of vehicle speed.

TRANSMISSION CONTROL

Shift Pattern

- Electric "Fuel-off Downshift."
- Later: more aggressive TCC, Slip-TCC, earlier upshifts.

Torque Converter Control

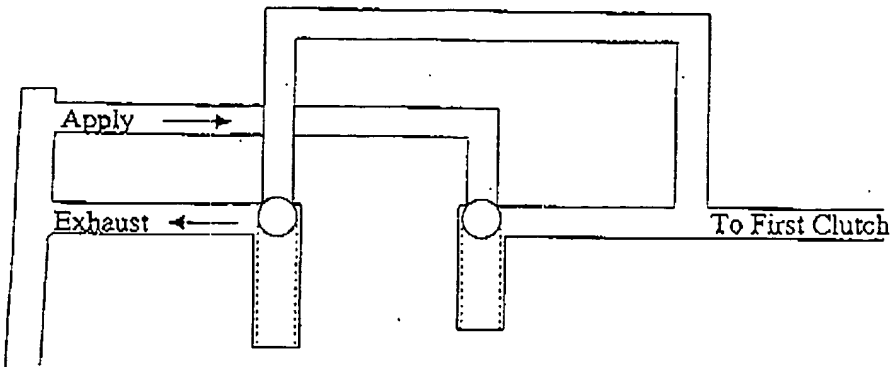
- Reverse-Freewheeler torque converter.

(Keeps engine spinning.)

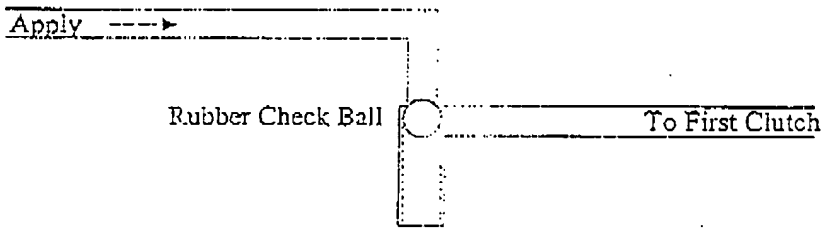
First-Clutch Check Valve

- Keeps 1st clutch engaged during engine-off stops.
- Before shutting fuel off, elevate line pressure.

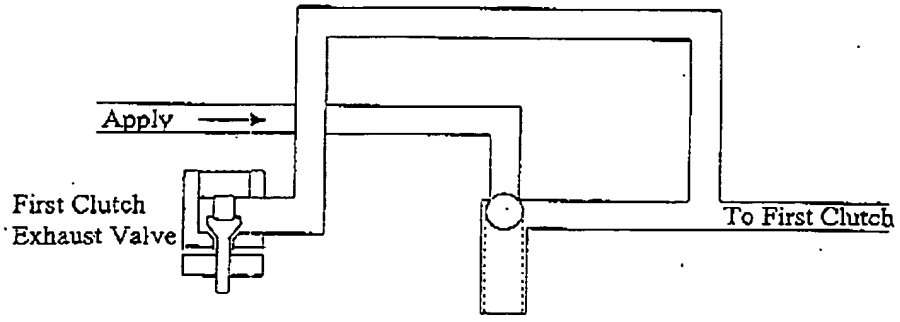
Production First Clutch Circuit

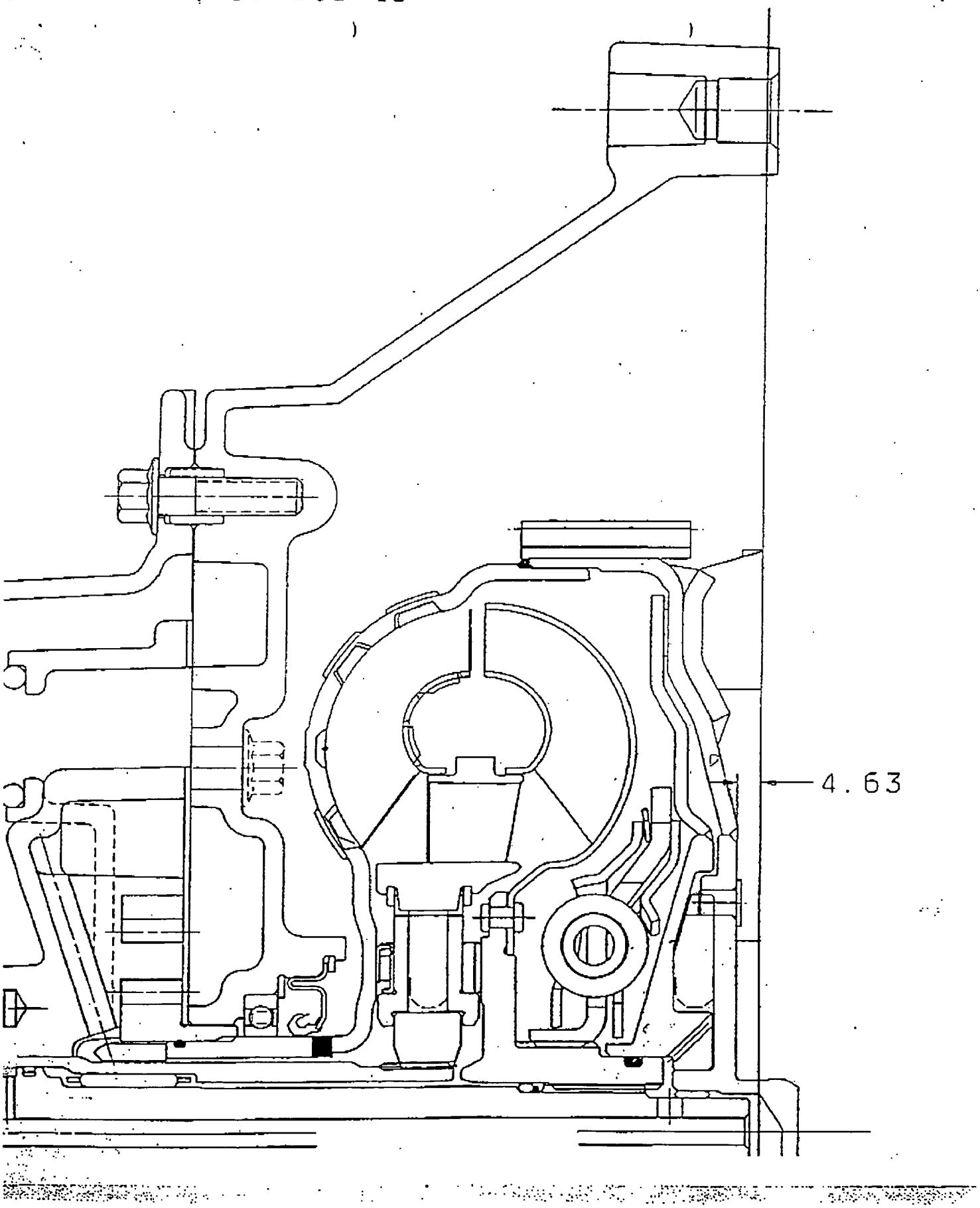


Modified First Clutch Circuit



Modified First Clutch Circuit with First Clutch Exhaust Valve





8 DEGREES OF HYBRIDIZATION

1. Cranking.
2. Full.
3. Full w/ Fuel-Aided Downshifts.
4. Decel only w/ and w/o I-Eliminator.
5. Decel only w/ Fuel-Aided Downshifts, w/ and w/o I-Eliminator.
6. None.

(Some features inactive on hills and in turns.)

EPA City MPG Improvement

= 15 ~ 30 %

depending on algorithm.

Actual Roadtrip MPG Improvement

= 10 ~ 20 %

Head-to-tail driving with 2~3 SL1-A/T prod. cars, ~1800 mi.

Answer the following questions, completing all of them to the best of your knowledge.

1. Date this invention was or is expected to be disclosed (including to a supplier) outside Saturn:

2. Date this invention was used or is committed to be used in production: Not Known.

3. Date this invention was offered for sale outside Saturn: Not Known.

4. Was this invention made while working on a Government Contract? ☐ Yes ☒ No

   If yes, identify the government Contract No. N/A.

5. Identify the product or process in which the invention is incorporated: Hybrid-electric vehicle.

6. Provide enough detail of the specific new features, components, or steps that form the invention to enable a general understanding of its technical content and novelty. The description should be referenced by numerals to an attached drawing, (if appropriate), that highlights the specific features, components, or steps of the invention including the environment or assembly in which the invention is incorporated.

Please see attached sheet (pages 7-9).

7. What are the competitive benefits to be realized through the use of this invention? For example: cost, quality and performance improvements, new features and products, etc.

The main benefit of the Saturn powertrain hybridization is increased fuel economy. To ensure that driveability and system reliability are not compromised, the hybrid system can have 8 degrees of hybridization ranging from full hybridization to no hybridization (fuel control scheme is same as that of a conventional powertrain).

8. To the extent known, what alternatives exist for accomplishing substantially the same result of this invention?

N/A for a conventional powertrain.

For another hybrid powertrain: none known.

9. What are the technical benefits obtained, problems solved, and advantages realized over the alternatives identified in Item #8?

N/A

10. What is the state of development of this invention?

A fully functional prototype vehicle has been built. Both mechanical and control systems are under continued development. Vehicle tests have shown very promising results.